NAMRL TECHNICAL MEMORANDUM 86-1

INCOMPATIBILITY OF THE M-1 MANEUVER WITH U. S. NAVY TACTICAL AIRCRAFT OXYGEN SYSTEMS

J. T. White, M.D., and L. M. E. Morin, M.D., Ph.D.

September 1986

NAVAL AEROSPACE MEDICAL RESEARCH LABORATORY
PENSACOLA FLORIDA

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION: UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT: Approved for public release; distribution unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S): NAMRL Technical Memorandum 86-1	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION: Naval Aerospace Medical Research Laboratory; 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION: Naval Medical Research & Development Command
6c. ADDRESS (City, State, and ZIP Code): Naval Air Station, Pensacola, FL 32508-5700	7b. ADDRESS (City, State, and ZIP Code): Naval Medical Command, National Capital Region, Bethesda, MD 20814-5044
8a. NAME OF FUNDING/SPONSORING ORGANIZATION: Naval Medical Research and Development Command; 8b. OFFICE SYMBOL (If applicable): Code 404	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code): Commanding Officer, Naval Medical Research & Development Command, Naval Medical Command, National Capital Region, Bethesda, MD 20814-5044	10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.
63706N	M0096	.01	1053

11. TITLE (Include Security Classification)
Incompatibility of the M-1 Maneuver with U. S. Navy Tactical Aircraft Oxygen Systems

12. PERSONAL AUTHOR(S)
J. T. White, M.D. and L. M. E. Morin, M.D., Ph.D.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM ______ TO ______	1986 September	8

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Acceleration, protective devices, G-induced LOC

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

A spectrum of clinical symptoms consisting of grey-out, black-out, and G-induced loss of consciousness has been identified in pilots of high performance aircraft. The M-1 maneuver used in conjunction with reclined seats and inflated G-suit provides significant protection against these symptoms. Centrifuge-trained United States Navy tactical aircraft pilots have recently reported a decreased ability to perform the M-1 maneuver while using the MBU-12P oxygen mask and CRU-79/P oxygen regulator. This report reviewed the performance specifications of these devices and compared them with published pulmonary flow rates. We found this oxygen system to interfere with the performance of the M-1 and other anti-G maneuvers. Further research is needed to characterize pulmonary flow rates during the performance of the M-1 maneuver in order to make recommendations for breathing system standards aboard high performance aircraft.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT: ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☒ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION
22a. NAME OF RESPONSIBLE INDIVIDUAL: J.O. HOUGHTON, CAPT MC USN, Commanding Officer	22b. TELEPHONE (Include Area Code): (904) 452-3286; 22c. OFFICE SYMBOL: 00

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete. SECURITY CLASSIFICATION OF THIS PAGE

*U.S. Government Printing Office: 1985-507-047

UNCLASSIFIED

SUMMARY

A spectrum of clinical symptoms consisting of grey-out, black-out, and G-induced loss of consciousness has been identified in pilots of high performance aircraft. The M-1 maneuver used in conjunction with reclined seats and inflated G-suit provides significant protection against these symptoms. Centrifuge-trained United States Navy tactical aircraft pilots have recently reported a decreased ability to perform the M-1 maneuver while using the MBU-12P oxygen mask and CRU-79/P oxygen regulator. This report reviewed the performance specifications of these devices and compared them with published pulmonary flow rates. We found this oxygen system to interfere with the performance of the M-1 and other anti-G maneuvers. Further research is needed to characterize pulmonary flow rates during the performance of the M-1 maneuver in order to make recommendations for breathing system standards aboard high performance aircraft.

INTRODUCTION

Grey-out, black-out, and G-induced loss of consciousness form a well established spectrum of clinical symptoms occurring in pilots of high performance aircraft (3). To combat this problem, several G protection systems and techniques have been developed, including: reclined seats, anti-G suits, positive pressure breathing, and anti-G straining maneuvers. Of these, the anti-G straining maneuvers are the most effective protective adjuncts, maximally extending the centrifuged-trained pilot's G tolerance by some 2-4 G above the 4-5 G "relaxed" tolerance obtained seat while wearing an inflated G suit (1,5).

Centrifuge-trained United States Navy pilots have recently reported a decreased ability to perform the M-1 maneuver while using the oxygen systems in tactical aircraft. The major problem that the pilots report is an inability to take a quick, deep inspiration due to insufficient oxygen flow. They also note that gas frequently leaks from around the mask when they are doing a modification of the M-1 maneuver, in which they only perform the maneuver for 3 seconds and therefore must rapidly exhale the gas remaining in their lungs at the end of this time. This report examines these reported problems with respect to published data on the M-1 maneuver, maximum inspiratory and expiratory flow rates, and the performance specifications of the oxygen systems utilized in tactical Navy aircraft.

Opinions and statements contained herein are those of the authors and are not to be construed as official or reflecting the view of the Navy Department.

M-1 MANEUVER

The M-1 maneuver is a particular type of anti-G straining maneuver originally described by Wood et al.:

> "Just before the g comes on with all your strength pull your chin in and your shoulders up. Simultaneously push your belly against a tightly drawn safety belt as if straining at stool. As you do this, yell the word 'Hey' as continuously as possible. Use up nearly all your breath on each 'Hey' then grab a very fast breath and immediately start yelling again. Keep this up as long as you hold the g." (13)

Since this original description, various modifications of the maneuver have been described and are compared in the review by Burton et al. (2). Common to all of these modifications is forced expiration against either a closed or partially closed glottis; this raises intrathoracic pressure and causes a resultant increased arterial pressure at eye level. If high G is sustained for longer than a few seconds, then the pilot must rapidly inspire and repeat the M-1 maneuver. In the case of the L-1 maneuver, in which exhalation is against a closed glottis, and thus no gas is lost while straining, the pilot must both rapidly expire and inspire before repeating the maneuver. In both these maneuvers, it is crucial that these respiratory gasps be short (approximately 1 s) or grey-out or unconsciousness may occur (2).

MAXIMUM INSPIRATORY AND EXPIRATORY FLOW RATES

Maximum inspiratory and expiratory flow rates have been reported by many authors (6,8,9,10) - see Table I. While there is a great deal of variability among these results -- owing to the dependence of expiratory flow on age, sex, and height; and the dependence of both expiratory and inspiratory flow on effort -- maximum expiratory and inspiratory flow rates are frequently depicted as 8 L/s (8).

Table I. Published maximal inspiratory and expiratory flow rates (L/s)

	Kory et al.	Fry & Hyatt	Hyatt*	Butler et al.	Hyatt**
Maximal Inspiratory Flow Rate	--	--	8.5(1.3)***	5.0-8.3	--
Maximal Expiratory Flow Rate	7.02(2.4)	4.0-8.5	8.5(1.6)	6.6-8.3	8.3-10.4
Number of Subjects	369	8	12	6	--

* Hyatt, 1961
** Hyatt, 1965
*** Values in parentheses () are standard deviations.
-- Not reported.

DESIGN SPECIFICATIONS OF TACTICAL AIRCRAFT OXYGEN SYSTEMS

The most widely used oxygen system in Navy tactical aircraft consists of: the CRU-79/P oxygen regulator (interposed between the lower high pressure hose and the upper low pressure hose), and the MBU - 12/P oxygen mask. A review of the performance specifications of this system shows both the inlet flow rate of the regulator and the inlet and outlet flow rate of the mask valve to have a performance flow standard of 0-100 L/min. (10,11,12). While these performance specifications are minimal standards, we are unaware of published work detailing the actual flow rate of this system.

DISCUSSION

It is readily apparent that the published maximal inspiratory and expiratory flowrates of 480 L/min (8 L/s) far exceed the performance specifications of the Navy's tactical aircraft oxygen system (0-100 L/min). It is reasonable to conclude that the difficulties being experienced by tactical aircraft pilots may be due to the system's inability to provide

sufficient inspiratory and expiratory flow rates during the M-1 maneuver. If this is the case, the problem is exacerbated by the L-1 maneuver, which includes both a rapid expiration and a rapid inspiration, thus increasing signficantly the time needed to perform the respiratory gasp. Current information is insufficient to localize the source of a possible flow restriction. It may be due to either a single component (ie, the mask, the regulator, the hose, or the valve) or any combination of these. Given the great importance of anti-G straining maneuvers in increasing G tolerance, aircraft oxygen systems need to be designed to accommodate not only average inspiratory and expiratory flow rates and pressures, but the high instantaneous rates of flow and changes in pressure that occur in a tactical environment while performing anti-G straining maneuvers. What is needed is a description of the respiratory flow rates of tactical aircraft pilots both under normal and simulated combat conditions. These human requirements can then form the basis on which the actual flow rates of tactical aircraft oxygen systems can be evaluated, and if necessary form a standard for making appropriate engineering changes.

Unfortunately, it is not now possible to recommend specific standards for tactical aircraft oxygen systems due to a lack of information on the pulmonary physiology involved in the M-1 or other anti-G maneuvers. While considerable data currently exist on lung physiology, most investigators have concerned themselves with the expiratory phase of flow volume loops under normal environmental conditions. Pilots of high performance aircraft must perform anti-G straining maneuvers under diverse environmental conditions including: high G, diverse atmospheric pressures, and varying amounts of positive pressure breathing. We are unaware of any published reports that characterize pulmonary flow during anti-G straining maneuvers

under these environmental conditions. Such studies need to be conducted in order to make recommendations for breathing system standards aboard high performance aircraft.

REFERENCES

1. Burton, R. R., "A conceptual model for predicting pilot group G tolerance for tactical fighter aircraft." Aviat. Space Environ. Med., Vol. 57, pp. 733-44, 1986.

2. Burton, R. R., Leverett, S. D., Jr., and Michaelson, E. D., "Man at high sustained $+G_z$ acceleration: a review." Aviat. Space Environ. Med., Vol. 45, pp. 1115-36, 1974.

3. Burton, R. R. and Whinnery, J. E., "Operational G-induced loss of consciousness: something old; something new." Aviat. Space Environ. Med., Vol. 56, pp. 812-7, 1985.

4. Butler, J., Caro, C. G., Alcala, R., and Dubois, A. B., "Physiological factors affecting airway resistance in normal subjects and in patients with obstructive respiratory disease." J. Clin. Invest., Vol. 39, pp. 584-91, 1960.

5. Cohen, M. M., "Combining techniques to enhance protection against high sustained accelerative forces." Aviat. Space Environ. Med., Vol. 54, pp.338-342, 1983.

6. Fry, D. L. and Hyatt, R. E., "Pulmonary Mechanics. A unified analysis of the relationship between pressure, volume and gasflow in the lungs of normal and diseased human subjects." Am. J. Med., Vol. 29, pp. 672-89, 1960.

7. Hyatt,R. E., "The interrelationship of pressure, flow, and volume during various respiratory maneuvers in normal and emphysematous subjects." Am. Rev. Respirat. Diseases, Vol. 83, pp. 676-83, 1961.

8. Hyatt, R. E., "Dynamic lung volumes." In W. O. Fenn and H. Rahn, (eds.), Handbook of Physiology. Vol. 2, Sec. 3. Washington: American Physiological Society, 1965, pp. 1381-1397.

9. Korv, R. C., Callahan, R., Boren, H. G., and Syner, J. C., "The veterans administration cooperative study of pulmonary function." Am. J. Med. Vol. 30, pp. 243-58, 1961.

10. Mask, oxygen MBU-12/P, MIL-M-67163A (USAF).

11. Regulator, chest mounted, 100 percent oxygen, positive pressure, CRU-79/P, MIL-R-81553.

12. Valve, oxygen mask, combination inhalation and exhalation, MIL-V-27296.

13. Wood, E. H., and Hallenbeck, G. A., "Voluntary (self protective) maneuvers which can be used to increase man's tolerance to positive acceleration." Fed. Proc., Vol. 4, pp. 78-9, 1945.

*U S. GOVERNMENT PRINTING OFFICE: 1987-730-013/65161 Region 4.